Vegetation, Invertebrate Distribution and Fish Utilization of the Campbell River Estuary British Columbia

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VEGETATION, INVERTEBRATE DISTRIBUTION AND FISH UTILIZATION OF THE CAMPBELL RIVER ESTUARY BRITISH COLUMBIA

by

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ABSTRACT

Water quality, vegetation, invertebrate and fish resources of the Campbell River Estuary were examined from April to August 1980. Water quality was within normal ranges. Among the seagrasses, *Zostera marina* and *Ruppia maritima* were the most common. *Enteromorpha intestinalis*, *Fucus* sp. and *Laminaria saccharina* were most representative of benthic macroalgae. Five brackish marsh communities were identified of which the *Deschampsia caespitosa* community was the most abundant. A total of 42 taxa of benthic macrofauna were identified. Common species were *Gnorimosphaeroma oregonensis*, *Eogammarus confervicolus*, *Corophium brevis* and *C. spinicorne*. Among the 18 species of fish captured, juvenile chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*) and pink salmon (*O. gorbuscha*) were the most abundant. Common prey species for juvenile salmon were copepods, mysids, aquatic and terrestrial insects, planktonic crustaceans and cladocerans. This study provides a baseline for evaluation of habitat restoration work initiated in 1981.

RÉSUMÉ

D'avril à août 1980, on a étudié la qualité de l'eau, la végétation et les ressources en invertébrés et en poissons de l'estuaire de la rivière Campbell. La qualité de l'eau était dans la normale. Parmi les herbes marines, Zostera marina et Ruppia maritima étaient les plus communes tandis que Enteromorpha intestinalis, Fucus sp. et Laminaria saccharina dominaient parmi les grandes algues benthiques. On a identifié cinq communautés en marais saumâtres dont celle composée de Deschampsia caespitosa était la plus importante. Au total, 42 taxons de macrofaune benthique ont été identifiés: Gnorimosphaeroma oregonensis, Eogammanus confervicolus, Corophium brevis et C. spinicorne étaient communs. Parmi les 18 espèces de poisson capturées, les juvéniles des saumons quinnat (Oncorhynchus tshawytscha), kéta (O. keta), coho (O. kisutch) et rose (O. gorbuscha) étaient les plus abondants. Ils se nourrissaient surtout de copépodes, de mysides, d'insectes aquatiques et terrestres et de crustacés et cladocères planctoniques. La présente étude servira de base à l'évaluation des travaux de rétablissement de l'habitat mis en oeuvre en 1981.

PREFACE

Field work for this study was conducted by the original authors in 1980 and a final draft report was produced in July 1981. The draft report has been used and cited by subsequent investigators, for example Brownlee *et al.*, 1984. The final draft was subsequently edited to produce this report. Much of the raw data contained in the final draft has been placed in a separate volume, available upon request

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INTRODUCTION

Estuaries are highly productive ecosystems providing nursery areas for fish and sources of organic material for other coastal ecosystems. The rearing of juvenile salmonids in British Columbia estuaries has been documented by Levy et al. (1979) and Healey (1979 and 1980) among others. Fish habitat in the Campbell River Estuary has been substantially reduced or degraded by man's activities. In particular, habitat has been lost or altered by filling, dyking, pile driving and log booming. In 1981, a dry land log soring facility was established to reduce industrial use of the estuary and a program of estuary rehabilitation was initiated (Brownlee et al., 1984).

The purpose of this report is to describe and map the habitats of the Campbell River estuary in terms of water quality, vegetation, and invertebrate macrofauna; and to present information on fish utilization of these habitats, with particular emphasis on feeding habits and growth of juvenile salmonids. This work, conducted in 1980, provides a useful baseline to evaluate the estuary rehabilitation work initiated in 1981.

STUDY AREA

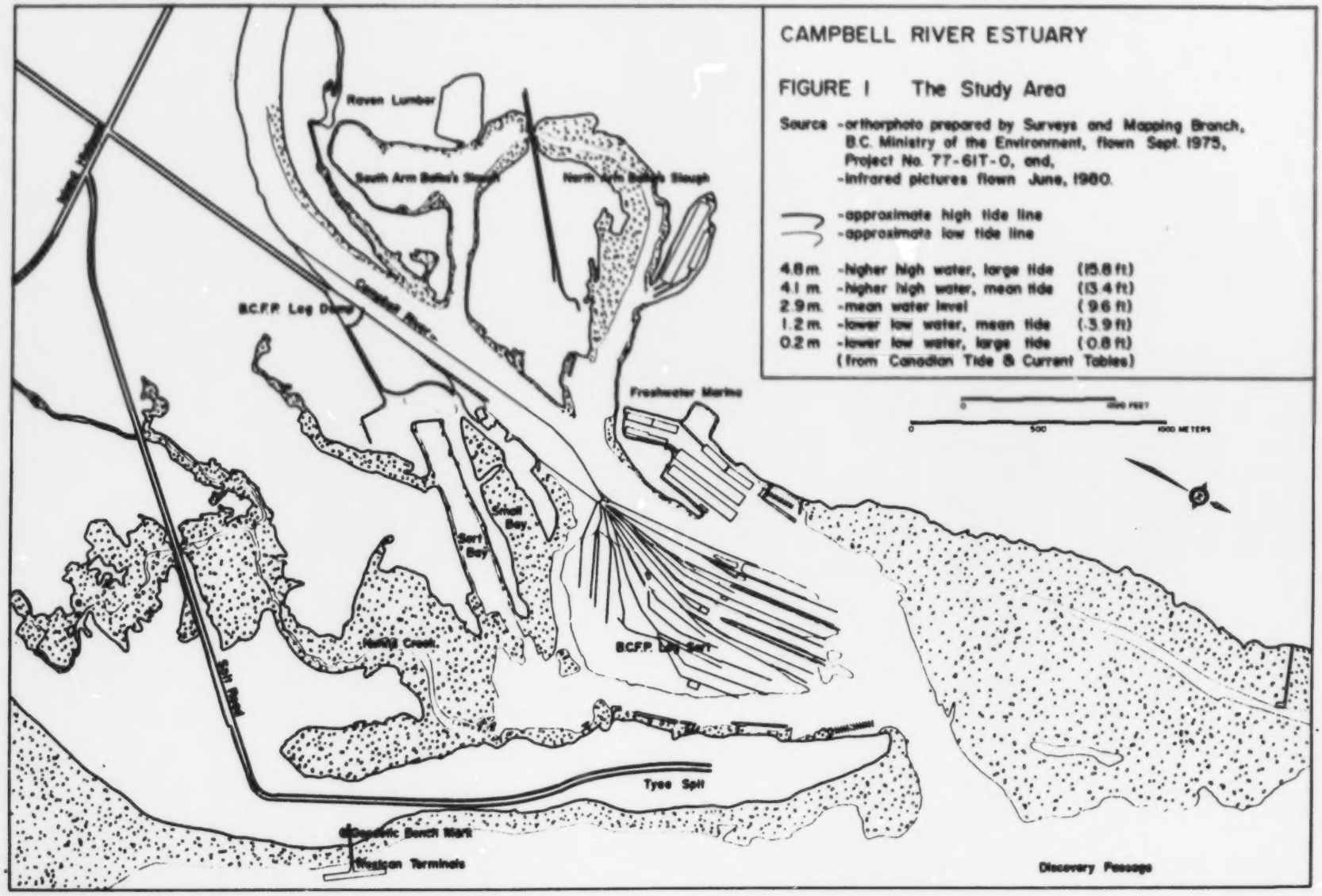
WATERSHED

The Campbell River is the third largest river in terms of discharge on the east coast of Vancouver Island. The annual discharge pattern is typical of Vancouver Island streams; ie. highest from October to February, and lowest from March to September. River flow at the estuary is the sum of the Quinsam and Campbell Rivers, with average annual discharge of 108 m^3/sec. (Department of Environment, 1976).

ESTUARY

The estuary is defined as an area of approximatey 73 ha behind Tyee Spit and a shallow gravel bar (Figure 1). Fresh water from the river is quickly dissipated from the estuary by the tidal currents of Discovery Passage. Nunn's Creek, in the southern corner of the estuary, contributes significant freshwater flow during heavy rains.

At the time of this study (1980), approximatey 60 percent of the estuary (43 ha) was utilized for log handling. The estuary also accommodates two marinas and several smaller floats used primarily by floatplanes. Since the study, an extensive rehabilitation program has taken place in the estuary. A dryland log-sort has replaced the water based log-sort area and several intertidal islands have been created and planted with marsh grasses. Followup studies have monitored plant growth, benthic community recolinization and fish utilization (Brownlee et al., 1984).


CAMPBELL RIVER ESTUARY
FIGURE 1 The Study Area
Source -orthorphoto prepared by Surveys and Mapping Branch, B.C. Ministry of the Environment, flown Sept. 1975, Project No. 77-61T-0, and,
-infrared pictures flown June, 1980.
-approximate high tide line
-approximate low tide line
4.8 m. -higher high water, large tide (15.8 ft)
4.1 m. -higher high water, mean tide (13.4 ft)
2.9 m. -mean water level (9.6 ft)
1.2 m. -lower low water, mean tide (3.9 ft)
0.2 m -lower low water, large tide (0.8 ft)
(from Canadian Tide & Current Tables)
Raven Lumber
South Arm Bella's Slough
North Arm Bella's Slough
B.C.F.P. Log Dump
Freshwater Marina
Sort Bay
Gravel Bay
Hamm Creek
B.C.F.P. Log Sort
Spit Road
Tyee Spit
Discovery Bench Mart
Weldcan Terminals
Discovery Passage

FISH RESOURCES

The Campbell/Quinsam river system supports five species of Pacific salmon, steelhead and cutthroat trout, and Dolly Varden char. Campbell River chinook support a sport fishery with a direct value of $5.5 million (1973 dollars) per 100 day tourist season and a net economic impact on the region estimated at 5-8 times this amount (Yeomens, 1973). Campbell River chinook and coho are harvested by the commercial fishery from the northern portion of the Strait of Georgia to southeastern Alaska, whereas chum and pink are taken almost exclusively in the Johnstone Strait net fishery.

Annual salmon escapements have been recorded since 1929, except for sockeye salmon, which are present only in the system in low numbers. Average annual escapements for the most recent 10-year period are presented below:

RIVER	SOCKEYE	CHINOOK	COHO*	CHUM	PINK
Campbell (1971-1980)	64	4,050	805	5,370	1,590 (odd) 4,013 (even)
Quinsam (1970-1979)	52	92	6,003**	666	9,652 (odd) 10,319 (even)

* does not include "surplus" adult and jack coho
** includes hatchery returns for 1976 to 1979 but not the lower Quinsam River sport catch.

A hatchery established on the Quinsam River in 1975 releases approximately one million chinook fry, 1.5 million coho smolts, and 20,000 steelhead smolts each spring. In 1980 two million pink fry were released. A colonization program is also being conducted, involving the release of approximately 200,000 coho fry and 17,000 to 35,000 steelhead fry in the upper Quinsam River.

MATERIALS AND METHODS

WATER QUALITY

Samples for dissolved oxygen concentration, were collected on 1 August 1980 at five sites (Annex 1). Samples were analyzed by the iodometric azide method as described in Standard Methods (American Public Health Association, 1975). Surface salinity and temperature were measured monthly from April to July at beach seine sampling sites with a YSI salinity meter.

VEGETATION

Seagrasses

Eelgrass presence and distribution was observed during low tide field sampling and by using low level false colour infrared aerial photographs (scale 1:4,000) flown 20 June 1980 at a 0.5 metre tide (based on Campbell River tide tables). Seagrass samples were collected for standing crop biomass estimates.

Benthic Macroalgae

Distribution, species composition and estimated coverage of benthic macroalgae was mapped from ground survey and aerial photography. Macroalgae samples for determination of standing crop biomass were collected during low tide (28 & 29 July 1980) from 9 areas (Annex I). Replicate quadrat samples (0.0625 m^2) were taken from sites of 100% cover within each area. Samples were frozen immediately after daily collection. In the

laboratory, samples were thawed, rinsed (to remove sediment) and blotted. Each sample was weighted (wet weight) and then oven dried to a constant weight (at 100°C for 24-48 hours) to determine standing crop biomass (g dry wt m^{-2}).

Benthic Microalgae

Benthic microalgae samples were collected at fifteen sites where the substrate was sand or mud and no macroalgae growth was observed (Annex 1). At each site, a minimum of 2 samples were collected and frozen for later determination of organic content and diatom communities. In the laboratory, samples were placed in pre-weighed aluminum dishes and oven dried at 100C to a constant weight then ashed in a muffle furnace at 500C for 4 hours. Organic content was calculated as follows:

$$\text{Organic Content (\%)} = \frac{(\text{dry weight} - \text{ash weight}) \times 100}{\text{dry weight}}$$

Biomass (g C m^{-2}) was estimated as 50% of the organic weight. In addition, a subsample was microscopically examined to identify the relative percentage of dominant diatom genera.

Marsh

Species composition and distribution of marsh emergent vegetation was determined by stereoscopic analysis of false colour infrared photography and by ground truthing. Maps of general plant distribution and recognizable communities were drawn from the airphotos onto an orthophoto of the estuary using a Map-O-Graph map production machine.

Seven transects (Annex 1) were sampled on 28 and 29 July 1980 with marsh communities identified according to the most abundant species. In addition, the presence of non-abundant species was noted for each community. Identifications were made according to Hitchcock and Cronquist (1976). Along each transect, plant material above the ground was sampled for analysis of standing crop. Replicate quadrat (0.25 m^2) samples were selected by "over the shoulder" or "closed eye" randomization. Samples were placed in plastic bags, and frozen upon completion of daily field sampling.

ZOOPLANKTON

Zooplankton was sampled at seven sites (Annex 1) on 1 August 1980 by five minute horizontal tows of a plankton net (0.25 m diameter opening and 351 micron mesh). Tows were made during a daytime high tide and the net was towed so it was just under the surface of the water. Samples were preserved in 2% formalin. In the laboratory, a volumetric subsample was obtained with a wide-mouthed pipette. A minimum of 100 organisms were counted and identified to genus for most taxa.

BENTHIC MACROFAUNA

Three to four replicate quadrat samples of benthic macrofauna were obtained during a low tide on 26 June and 30 July 1980 (Annex 1). Samples were preserved in 4% formalin buffered with sodium borate. In the laboratory, macrofauna were separated from plants, debris, and sediments using elutriation and sieving. Samples were stirred in a bucket and poured through 40 mm and 0.5 mm sieves. Larger debris was retained on the 40 mm sieve was

discarded. Macrofauna were sorted from the material retained on the 0.5 mm sieve by stereomicroscope. Sorting was facilitated by staining samples with rose bengal dye (100 mg/l). Samples that contained large amounts of debris or large numbers of animals were subsampled by weight before sorting. Fauna were identified to species for most taxa. Dry weight of the June samples was also measured.

FISH

Field Methods

Fish were sampled monthly from March to July 1980 at fifteen high tide and fifteen low tide sites in the estuary (Annex 1). At each site, two replicate samples were obtained with a 15 m by 2 m beach seine (6.4 mm mesh in wings and 3.2 mm mesh in bunt). All fish were enumerated, identified to species and most were preserved for laboratory analysis. When large numbers of salmonids were captured, a subsample was preserved.

Laboratory and Analysis Methods

Preserved fish were blotted dry, measured to the nearest mm (fork length for fish with forked tails) and weighed to the nearest mg. Scales were removed from juvenile salmonids to determine age and distinguish between hatchery and wild fish. Fulton's condition factors were calculated for juvenile salmon using the following formula:

$$K = 100\ w/l^3$$

where: w = weight
l = length

Fish stomachs were removed (from the esophagus to the junction of the pyloric caecae and intestine), opened and a subjective estimate of the percent fullness made. Food items were separated by gentle agitation and individual items identified and measured under a stereomicroscope. The percentage of the contents in an advanced state of digestion was estimated.

For analysis purposes stomach samples were grouped by habitat types based on location, substrate, vegetation and tide height. Only the stomachs of abundant species were analyzed each month ie. chum in April and May; chinook in April, May, June and July; and coho in May and June. A subsample of ten stomachs was examined for each species, habitat type and month.

Wet weight of food organisms was calculated from length data using formulae derived by Sibert (unpublished data). Indices of relative importance (I.R.I.) were then calculated for each food item by the following formula (Pinkas et al., 1971):

$$I.R.I. = (\%N + \%W) \times FO$$

where: N = number of organisms
W = wet weight
FO = frequency occurrence

Mark/Recapture Experiments

Fluorescent grit dye (Healey et al., 1976) was used to mark fish for population estimates. The grit was applied using a sandblast gun attached to a SCUBA tank at 7 kg cm^{-2} pressure. Approximately 50 fish were placed on a screen and the grit was applied from a distance of about 5 cm. After marking, fish were held for several hours to observe mortality and mark retention, then eunumerated before release.

The purpose of the mark/recapture experiment was to estimate the numbers of fish residing in each of two areas in the estuary and thereby determine the relative degree of utilization of these areas by salmonids. For this purpose, fish from Baikie's Slough and Nunns Creek mouth were treated as discrete populations and marked with different colours. Marked fish were released on 12 May and 9 June 1980. Fish were recaptured by beach seining for two nights after each release and were checked for fluorescent grit marks by inspection under an ultraviolet light source. Juvenile salmonids captured and preserved for length/weight determination at the end of May and June were also examined for flourescent dye. Population estimates were calculated using Petersen's single census method (Ricker 1975):

$$N = \frac{MC}{R}$$

where N = population estimate
M = number of marked fish
C = total of recaptured fish
R = number of marks, recaptured

RESULTS AND DISCUSSION

WATER QUALITY

Dissolved oxygen concentrations ranged from 5.9 to 7.5 mg/l. EVS Consultants (1978) reported depressed oxygen levels in the south arm of Baikie's Slough and in Sort Bay, possibly due to large amounts of wood wastes. Oxygen depression was not observed during this study.

Surface salinities were generally less than 4 $^{o}/_{oo}$ throughout the estuary on all sampling dates except during high tides at the end of Tyee Spit. At this site the salinity ranged from 5.9 $^{o}/_{oo}$ (July) to 22.0 $^{o}/_{oo}$ (April).

Temperatures in the estuary ranged from 8.0 to 15.7C in April and from 14.0 to 22.2C in July. The highest temperature was encountered on the outer edge of the estuary during a low tide.

ESTUARINE VEGETATION DISTRIBUTION AND BIOMASS

Seagrasses

The preferred habitat of eelgrass (*Zostera marina*) is characterized by salinities of 10 to 30 $^{o}/_{oo}$, temperatures of 10 to 20C, sand or silty sand substrate, low wave shock and depths of 1 to 4 m at mean lower low water. The upper limit of *Z. marina* growth is determined by the dessication of the plant (function of the tidal exposure and substrate) and the lower limit is primarily controlled by light availability. The most extensive eelgrass beds in the Campbell River estuary are located along the

edge of the sand/gravel bar at the mouth of the estuary and around the spit where the water is more saline (Figure 2). The estuary does not have extensive sand or mud flats at the elevation preferred by eelgrass except at these areas. Eelgrass is important as a refugia and attachment site for animals, as a stabilizer and colonizer of soft substrates and with its attendant epiphytes, a source of food primarily via the detrital chain.

Ruppia maritima generally grows in intertidal areas on sand and mud substrate often in flowing water of low salinity. In the Campbell River estuary, R. maritima was found only in two areas (Figure 2).

The standing crop biomass of R. maritima at the Sort Bay Creek site was 767 g dry wt. m^{-2}. This represents a biomass value comparable to many emergent vascular plant communities; however, due to the limited distribution of R. maritima its contribution to the total biomass of the estuary is low. The biomass of Z. marina at the sand/gravel bar area was 87 g dry wt. m^{-2} which falls within the lower range of values of reported by Moody (1978a) for Roberts Bank (59 to 207 g m^{-2}). This lower value may result from eelgrass being collected at higher elevations in the Campbell River estuary compared to Roberts Bank.

Benthic Macroalgae

Euryhaline chlorophytes were found throughout the estuary and were dominant in the southern inner part of the estuary (Figure 3). The predominant chlorophyte was Enteromorpha intestinalis which occurs on rocks in the upper intertidal zone, often at the head of creeks (areas of flowing water) or in places of

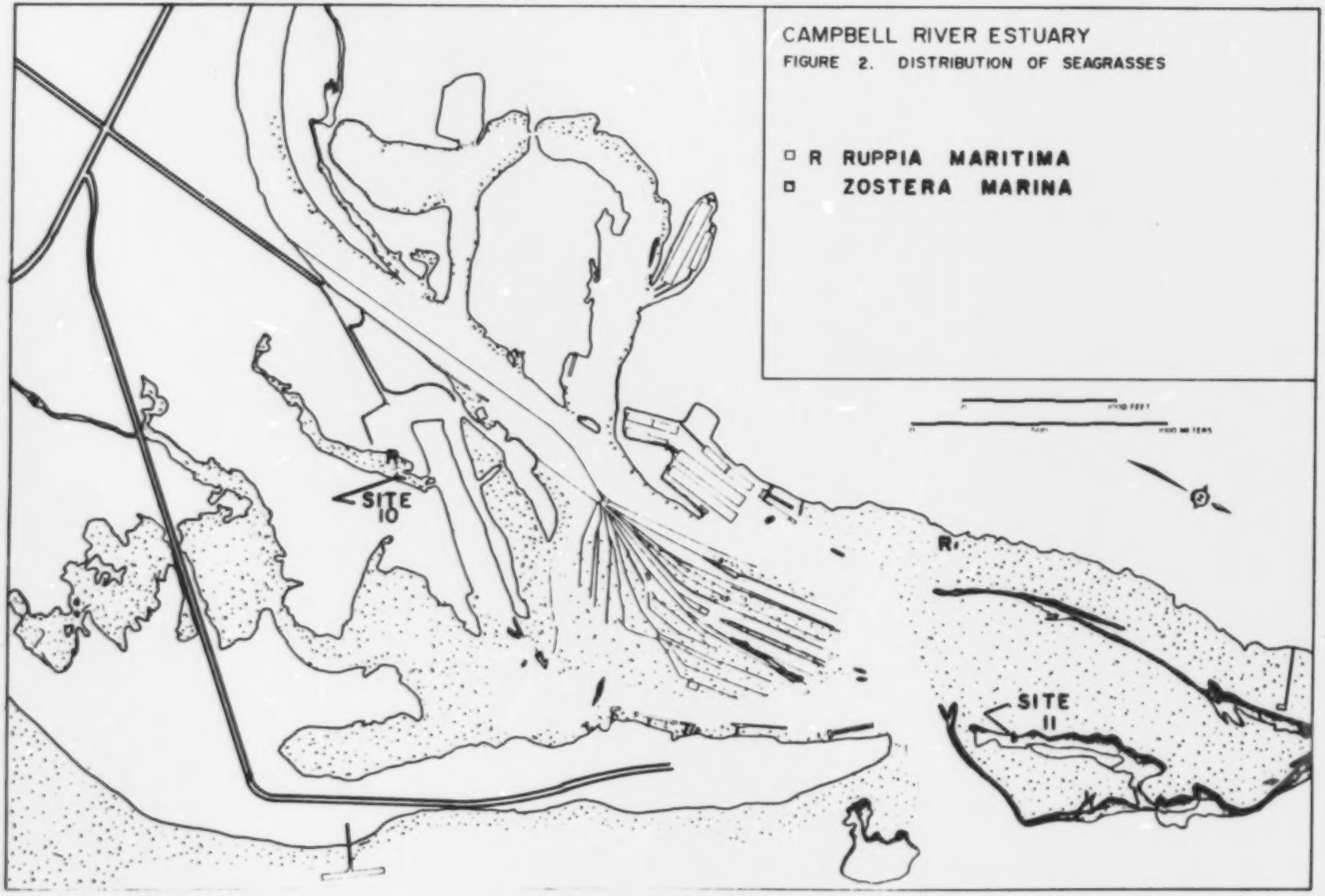

CAMPBELL RIVER ESTUARY
FIGURE 2. DISTRIBUTION OF SEAGRASSES
R RUPPIA MARITIMA
ZOSTERA MARINA
R
SITE 10
R
SITE 11

Table 1 Macroalgae Standing Crop Biomass.

Location	Sample Site	Replicate	Standing Crop	Mean Standing Crop (g dry wt. m^{-2})	Species
Nunns Creek	1	1	55	155	Enteromorpha linza
		2	256		
	2	1	635	838	Enteromorpha intestinalis
		2	1,040		
	3	1	3,464	3,464	Pelvetia limitata
Small Bay	4	1	88	90	Enteromorpha intestinalis
		2	92		
	5	1	402	50	Pelvetia limitata
		2	298		
Sort Bay	6	1	99	114	Enteromorpha intestinalis
		2	130		
Main Channel	7	1	27	34	Enteromorpha intestinalis
		2	42		
Freshwater Marina	8	1	44	50	Enteromorpha intestinalis
		2	56		
Sand/Gravel Bar	9	1	150	150	Ulva latuca

freshwater seepage. Entermomorpha linza was less prevalent in the estuary, inhabiting the lower intertidal zone where salinities are higher than E. intestinalis can tolerate.

Five standing crop biomass samples of E. intestinalis were collected throughout the estuary in areas where the cover of this species was 100%. Mean biomass values ranged from 34 g dry wt. m^{-2} in the main river channel to 838 g. dry wt. m^{-2} on the bar at the mouth of Nunns Creek (Table 1). The lower value may reflect higher water velocities present along the main channel. The maximum value, which is within the upper range for many vascular estuarine plants, illustrates the potential productivity in optimum growth areas (Pomeroy, pers. comm.).

The mean standing crop biomass of E. linza near the mouth of Nunns Creek was 155 g dry wt. m^{-2} (Table 1). Since E. linza does not grow in large dense mats (Pomeroy, pers. comm.) the biomass was less than that found for E. intestinalis at an adjacent site.

Another strongly eurhaline chlorophyte present throughout the estuary is the sea lettuce Ulva lactuca. This species was found primarily on a sand/gravel bar at the mouth of the estuary and in scattered areas of the log sort complex. The standing crop biomass on the bar was 150 g dry wt. m^{-2}, which is slightly higher than that reported for Roberts Bank (112.7 $\pm$ 16.6 g dry wt. m^{-2} [Beak Hinton, 1977]). The only other chlorophyte identified was Cladophora sp. This euryhaline species was, found in the lower intertidal zone adjacent to, and in isolated areas on, the sand/gravel bar.

Among the low salinity tolerant marine phaeophytes, Fucus sp. was found in cobble areas of the middle and lower intertidal zone where there was fairly good water movement. Fucus sp. covered

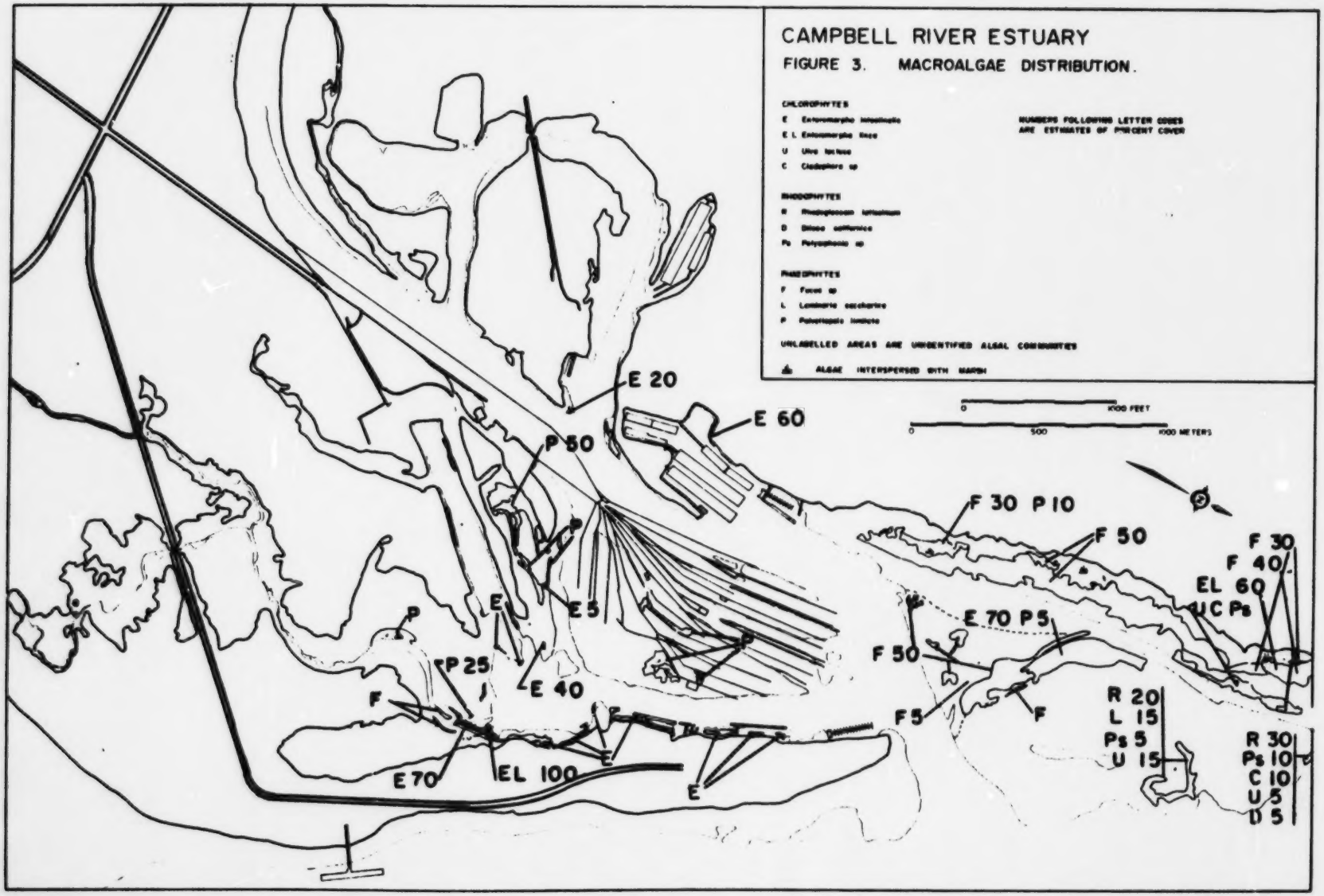
extensive areas of the sand/gravel bar and extended along the northwest shore below [illegible], in some cases interspersed within, the fringes of lower marsh (Figure 3). Although Fucus sp. will grow in brackish waters (as evidenced by growth in the brackish marsh) sexual reproduction will be inhibited and continued growth must rely upon seeding from an external source (Pomeroy, pers. comm.).

Laminaria saccharina was found on rocks in the lower intertidal and upper subtidal zones, at lower elevations than Fucus sp. It was present only on the gravel bar in association with several species of red algae.

Another Fucales, Pelvetia limitata was a common drift algae in embayments (Sort Bay and Small Bay) and the log sort. It is not known how stable the drift masses of P. limitata were or whether the plants were actively photosynthesizing. P. limitata occurs on rocks exposed to surf in the upper intertidal (Scagel, 1972) and hence represents an external source of organic material input into the estuary. The location of this algae in certain areas of the estuary is indicative of possible tidal and current "deposition sites" for mobile organic material (Figure 3). These sites can provide excellent refugia for benthic invertebrates on falling tides.

Standing crop biomass values for P. limitata were 350 g dry wt. m^{-2} in Small Bay and an order of magnitude greater (3,464 g dry wt. m^{-2} at a more confined natural entrapment area in Nunns Creek (Table 1). These high biomass values may be due to the morphology of the plant, which has more body and consequently a heavier organic load than the chlorophytes. In addition, very dense clumping of this species was observed in certain areas.

The Rhodophyceae were located primarily in two areas surrounding elevated gravel patches on the bar at the mouth of the estuary


CAMPBELL RIVER ESTUARY
FIGURE 3. MACROALGAE DISTRIBUTION.
CHLOROPHYTES
E Enteromorpha intestinalis
E L Enteromorpha linza
U Ulva lactuca
C Cladophora sp
RHODOPHYTES
R Rhodoglossum latissimum
D Dilsea californica
Ps Polysiphonia sp
PHAEOPHYTES
F Fucus sp
L Laminaria saccharina
P Pelvetiopsis limitata
UNLABELLED AREAS ARE UNIDENTIFIED ALGAL COMMUNITIES
ALGAE INTERSPERSED WITH MARSH
NUMBERS FOLLOWING LETTER CODES ARE ESTIMATES OF PERCENT COVER
0 1000 FEET
0 500 1000 METERS
E 20
E 60
P 50
F 30 P 10
F 50
F 30
F 40
EL 60
U C Ps
E 70 P 5
F 50
E 5
E 40
P 25
F 5
R 20
L 15
Ps 5
U 15
R 30
Ps 10
C 10
U 5
D 5
E 70
EL 100

(Figure 3). Red algae are predominately marine and found in the lower intertidal and subtidal zones (Chapman and Chapman, 1973). The most common species found in the estuary were Rhodoglossom latissimum and Dilsea californica (both found on rocks in the lower intertidal and subtidal zones) and the filamentous Polysiphonia sp.

The importance of benthic algae in an estuarine system may be related more to the manner in which they contribute energy to the system rather than the total energy produced. Pomeroy (1977) found that in the Squamish estuary benthic algae provided a continuously available and readily utilizable source of energy for invertebrates, such as amphipods, since there was little lag time between production, decomposition and utilization in detrital pathways.

Benthic Microalgae

The penate diatoms Achnanthes spp., Navicula spp. and Nitzschia spp. accounted for 68-95% of the numbers at all sample sites (Table 2). Achnanthes spp. was dominant on clay and sand substrates in the log sort area, Sort Bay Creek, and Small Bay. Navicula spp. was found in Nunns Creek and Sort Bay on sand and clay-silt sediments. This species tends to be more tolerant of sand substrate than the other diatom species (Munroe, pers. comm.). Nitzschia spp. was most abundant in the North Arm of Baikie's Slough. Achnanthes spp. and Navicula spp. were also common in Baikie's Slough, each contributing approximately one-fifth to one third of the percent abundance.

The highest biomass values for benthic microalgae were found in the clay-silt substrates of the North Arm of Baikie's Slough,

Table 2 Percent Abundance of Diatoms in Campbell River Estuary

Location	Nunns Creek			Sort Bay		Sort Bay Creek	Small Bay	Log Sort	North Arm of Baikie's Slough			Main Channel		Outer Gravel Bar	Inner Gravel Bar
Site No.	1	2	4	5	6	8	7	9	11	12	13*	3	10	GB1	GB2
GENERA															
Achnanthes spp.	28	38	27	33	36	72	74	63	22	23	33	49	51	59	21
Navicula spp.	42	38	39	44	32	11	12	13	28	32	30	32	28	26	30
Nitzschia spp.	25	15	12	6	20	11	4	5	27	24	25	4	15	8	11
Melosira sp.	0	0	5	1	0	0	0	0	8	2	0	0	0	1	13
Fragilaria sp.	2	0	0	2	0	0	7	19	4	0	1	1	0	2	0
Amphora sp.	2	4	4	1	2	0	2	0	2	2	0	10	3	1	6
Other spp.**	1	8	13	13	10	6	1	0	9	17	11	4	3	3	19

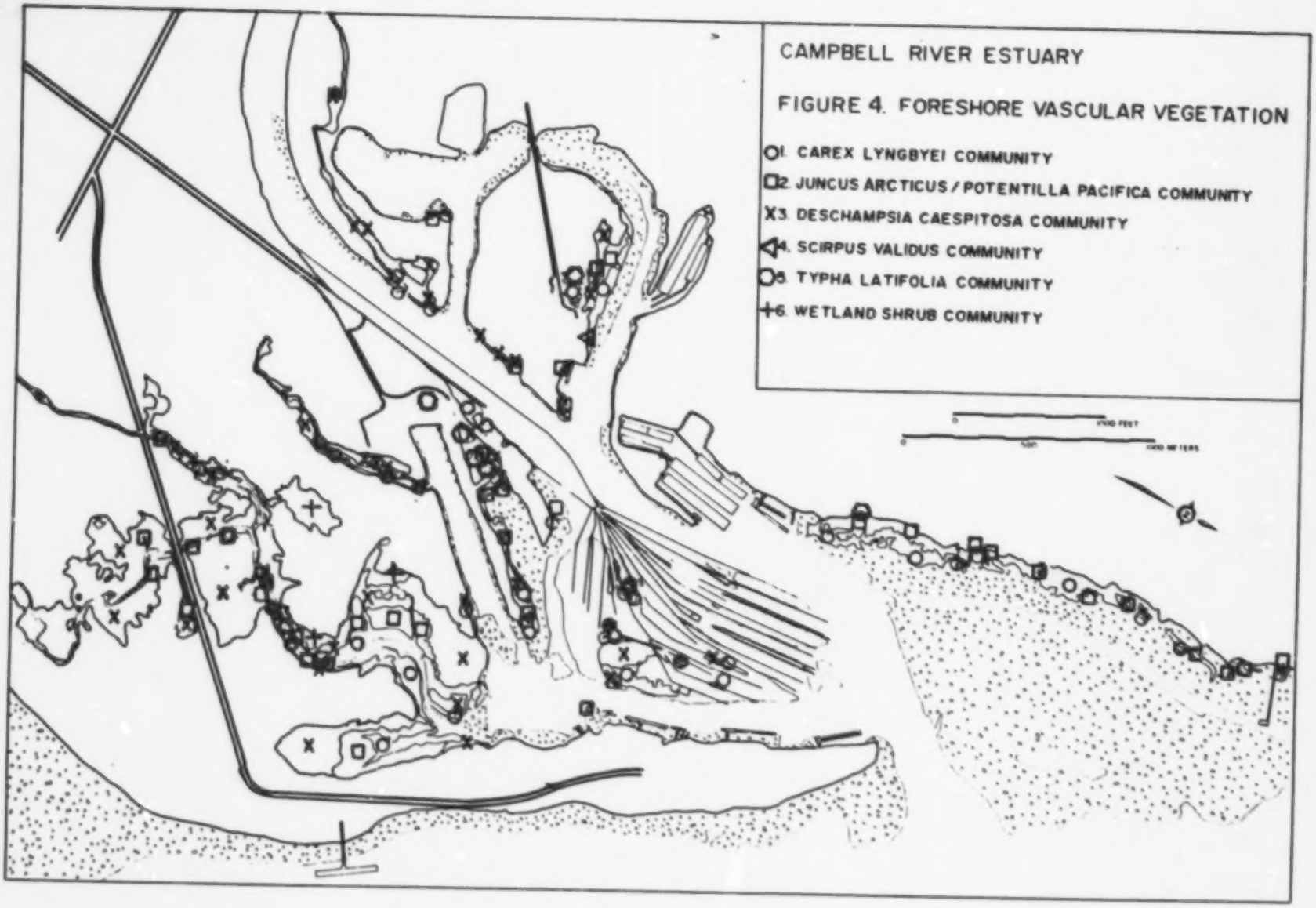
* Numerous small fibres in sample

** Cyclotella spp., Thalassiosira sp., Hannaea arcus, Opephora sp., Synedra spp., Tabellaria fenestrata, Cocconeis sp., Cymbella spp., Denticula sp., Diploneis sp., Gomphonema sp., Gyrosigma sp., Mastogloia sp., Nedium sp., Pinnularia sp. Rhoicosphenia curvata, Rhopalodia gibba, Stauroneis spp., Surirella sp., Tropidoneis sp.

(487 g C m^{-2}) and Nunns Creek (417 g C m^{-2}). These sites were adjacent to marshes where carbon could come from marsh detritus in addition to diatoms. Lower biomass values were found in sand sites at the Main Channel (59 g C m^{-2}), Sort Bay (101 g C m^{-2}) and near the mouth of Nunns Creek (117 g C m^{-2}). Although these values are lower overall, the ratio of carbon contribution from diatoms in relation to detritus is probably higher than in the clay-silt/marsh areas.

Brackish Marsh Vegetation

Five brackish marsh communities were identified in the estuary (Figure 4). The sedge community dominated by Carex lyngbyei occupied 5.5 ha (21%) of the intertidal marsh area of the estuary. C. lyngbrei is often a colonizer of clay-silt substrates and grows in a fairly wide elevation range on well drained substrates (Envirocon, 1980). In the Campbell River estuary, C. Lyngbyei was found in clay-silt, silt-sand, and even cobble areas on the northern shore of the estuary. The sedge community grew in an elevation range of 2.5 to 3.0 meters above chart datum. At this elevation the community was inundated by up to 70% of the tides during the growing season. At lower elevations, often along creek margins, a monospecific sedge community was found. The sedge growing in these areas is the "tall" form which is much larger and more vigorous than the "short" form found in the upper, drier, and more saline marsh areas. A "short" form of sedge, likely the result of high salinities, was observed along the north shore of the estuary amongst the Fucus sp. Sedge in the Squamish estuary also exhibited these two ecotypes (Levings and Moody, 1976). A significant characteristic of C. lyngbyei is its ability or produce substantial amounts of detritus (Kistritz and Yesaki,


CAMPBELL RIVER ESTUARY
FIGURE 4. FORESHORE VASCULAR VEGETATION
1. CAREX LYNGBYEI COMMUNITY
2. JUNCUS ARCTICUS / POTENTILLA PACIFICA COMMUNITY
3. DESCHAMPSIA CAESPITOSA COMMUNITY
4. SCIRPUS VALIDUS COMMUNITY
5. TYPHA LATIFOLIA COMMUNITY
6. WETLAND SHRUB COMMUNITY

1979) and thereby contribute to the detrital food chain which predominates in the ocean (Naiman and Sibert, 1979; and Pomeroy, in prep.).

Along the western edge of Nunns Creek in clay-silt substrate, red-tipped C. lyngbyei was observed. This condition might be caused by an increase in iron and manganese resulting from increased submergence (Hutchinson, pers. comm.).

The rush Juncus arcticus and Pontentilla pacifica dominated the second community covering about 4.5 ha (18%) of the marsh. Juncus arcticus occurred in small islands of monospecific stands at low elevations and as large diverse expanses with the subdominant P. pacifica at higher elevations. Juncus arcticus, like C. lyngbyei, requires well drained soils. The average elevation range for this community was 2.9 m (which is the mean tidal level at Campbell River) to 3.3 m. During the growing season the community was inundated by 63% of the tides.

The Deschampsia caespitosa (tufted hairgrass) community found in the upper marsh was the most diverse. A greater diversity of plants may become established in the upper marsh due to lower physiological stress (Odum, 1971). This community, the most abundant in the estuary covering 15.6 ha or 60% of the marsh, occurred from 3.4 m to 4.1 m and was inundated by approximately 49% of the tides. D. caespitosa is found in fresh to brackish areas but can not tolerate long periods of inundation or saline water.

The Scirpus validus (bullrush) community was present in few areas at the estuary (>0.1 ha). S. validus grows in almost pure stands, or associated with Eleocharis palustris and/or C. lyngbyei. It grows best on silty clay sediments (Barko and

Smart, 1978) in fresh or slightly brackish water. The bullrush community in the Campbell River estuary occurred at the same elevation as the lower range of the sedge community (2.5 m).

The Typha latifolia (cattail) community generally grows in specialized locations with groundwater discharge or standing water but can also tolerate brackish conditions (U.S. Army Engineers, 1978). In the Campbell River estuary, cattail is a minor community occupying only 0.3 ha (1%) of the intertidal marsh area. This community occurred on averaged at 4.1 m, being inundated by approximately 25% of the tides during the growing season. As a result of infrequent tidal inundation, little detrital material is removed from the community and numerous dead stalks were present.

In addition to the five brackish marsh communities, a wetland shrub community (commonly Myrcagale) was identified. This community was inundated only occasionally and has marsh plants interspersed with the shrubs. Upland of this community are the terrestrial shrub/tree communities.

Although plant communities do not exist as discrete units (i.e. a dominant plant in one community may also be present in another), their distributions do represent ranges of tolerance in response to certain environmental factors. The major factors influencing marsh establishment and community structure are substrate texture and elevation (which influence nutrient retention, soil aeration and salinity), nutrient availability, groundwater level, freshet discharge and species competition. The lower limit of species establishment is related to the lack of aeration due to tidal inundation, turbidity, current and salinity. The higher elevation limit is primarily controlled by physical exposure and species competition (Envirocon, 1980).

Standing crop biomass was calculated for the five marsh communities (Table 3). The C. lyngbyei community had the highest mean biomass (683 g dry wt. m^{-2}) of the five communities. For the tall C. lyngbyei ecotype in either monospecific stands or with few associated species mean biomass was 777 g dry wt. m^{-2} with maximum values as high as 1,132 g dry wt. m^{-2}. Similar biomass values for sedge communities have been found in other estuaries, for example, Squamish (1,322 g dry wt. m^{-2}; Levings and Moody, 1976) and Fraser (909 g dry wt. m^{-2}; Moody, 1978b). C. lyngbyei is often the most productive marsh plant species in an estuary. This species has an advantage over most others as overwintering shoots provide an early start to spring growth.

Mean biomass for the Juncus arcticus/Potentilla pacifica commuity was 550 g dry wt. m^{-2}, although pure rush stands had higher values (669 g dry wt. m^{-2}). Similar biomass figures for J. arcticus were recorded in James Bay (569 g dry wt. m^{-2}; Glooschenko, 1978); however, in the Squamish Estuary Lim and Levings (1973) reported a biomass of 1,098.2 g dry wt m^{-2} for this community. The average biomass of the Deschampsia caespitosa community (571 g dry wt. m^{-2}) was lower than that found in the Squamish Estuary (715.7 g dry wt. m^{-2}; Lim and Levings, 1973).

The Scirpus validus community had both the lowest biomass (190 g dry wt. m^{-2}) of all marsh communities in the estuary representing approximately one-half the value found at Squamish (400 g dry wt. m^{-2}; Lim and Levings, 1973). S. validus can exhibit significant differences in biomass depending upon substrate.

The average cattail community biomass was 490 g dry wt. m^{-2} similar to values on the Fraser Estuary (517 g dry wt. m^{-2} Yamanaka, 1975).

Table 3 Marsh Community Areas and Biomass.

Community	Area (ha)	Percent of Intertidal Marsh	Mean Biomass g dry wt. m^{-2}
Carex lyngbyei	5.5	21	683
Juncus arcticus/ *Potentilla pacifica*	4.5	18	550
Deschampsia caespitosa	15.6	60	571
Scirpus validus	>0.1	>1	190
Typha latifolia	0.3	1	490
TOTAL	25.9		

Estuaries are among the most productive ecosystems on earth (Odum, 1971). This is attributable to several factors including long growing season; vertical orientation of most leaves, which reduces heating and exposes maximum leaf surface to sunlight; high concentration of organic matter in the soil, which leads to the formation of colloids that absorb exchangeable ions necessary for plant growth; high water table, which holds dissolved nutrients; nutrient input from both the freshwater and marine systems; and the trapping of these nutrients caused by entrainment and the resultant flocculation of sediments.

ZOOPLANKTON

Freshwater cladocerans and copepods (primarily planktonic forms) were the dominant taxa in zooplankton samples. These species probably originated in lakes upstream of the estuary. Northcote et al. (1976) collected similar species in daytime surface tows on the lower Fraser River; however, Levings and Coustalin (1975) found primarily epibenthic marine and estuarine crustaceans such as Eogammarus sp. and Corophium sp. in plankton tows on Sturgeon Banks. Levings (1974) also found large numbers of insects in plankton tows in the lower Squamish River. It is possible that insects and epibenthic crustaceans would have been taken in plankton tows at the Campbell River estuary, had they been collected at night.

BENTHIC MACROFAUNA

A total of 42 taxa were found in benthic macrofauna samples, the most common and abundant being Gnorimosphaeroma oregonensis, Eogammarus confervicolus, Corophium brevis, C. spinicorne,

Oligochaeta, and Polychaeta. Differences in abundance of benthic invertebrates among sample sites in June were found to be not significant. On the other hand, there were significant differences in abundance between sample sites in July. Benthic invertebrates were more abundant at sites #2 ($\bar{x}$ 62,894 m^{-2}), #3 ($\bar{x}$ 57,045 m^{-2}), #4 ($\bar{x}$ 63,691 m^{-2}), and #5 ($\bar{x}$ 28,011 m^{-2}) which had mud and sand substrates compared with Site #1 ($\bar{x}$ 7,918 m^{-2}) which had a gravel substrate. Benthic invertebrate abundance at Site #9 in the south arm of Baikie's Slough was lower ($\bar{x}$ 971 m^{-2}) than at any other site.

Gnorimosphaeroma oregonensis

Abundance of G. oregonensis in benthic quadrat samples ranged from 16 m^{-2} to 5,056 m^{-2} in June and from 0 m^{-2} to 27,424 m^{-2} in July. Distribution appeared to be positively correlated with with the presence of gravel and macroalgae. Regression of abundance of G. oregonensis versus dry weight of macroalgae indicated that there was a positive correlation at sites "Nunns Creek", "North Spit" and "Gulf Air 1". Highest numbers of G. oregonensis were collected at sites characterized by gravel and algae at the mouth of Nunns Creek ($\bar{x}$ 6,117 m^{-2}) and at the mouth of the creek in Sort Bay ($\bar{x}$ 1,696 m^{-2}).

Abundance of G. oregonensis in the Campbell River estuary appears to be greater than other estuaries. In the Squamish Estuary, Levings and McDaniel (1974) reported a maximum density of 2,304 m^{-2}. On the banks of the Fraser River estuary, G. oregonensis occurred in only three of 120 samples collected by Levings and Coustalin (1975) with an average density of 32 m^{-2}.

Eogammarus confervicolus

Abundance of E. confervicolus in June ranged from 32 m^{-2} to 31,808 m^{-2}, and in July from 0 m^{-2} to 4,192 m^{-2}. Similar densities have been reported from Sturgeon Banks (x 960 m^{-2}; Levings and Coustalin (1975) and in mud/lower marsh habitats of the Squamish Estuary (3,800 m^{-2}; Levings, 1978). Distribution of E. confervicolus appeared to be positively correlated with algal or wood debris. Highest densities were often found in sites with either Pelvetia sp. or wood debris whereas lowest numbers were associated with mud and sand sites with no algae or debris. However, abundance of E. confervicolus was a negatively correlated with macroalgae dry weight at Site "Gulf Air 1". During July a thick mat of Pelvetia sp. was observed in Small Bay with an odor of hydrogen sulphide, suggesting anoxic conditions under and in the algae. Levings and McDaniel (1976) found that E. confervicolus showed signs of stress at oxygen levels below 20% saturation. In contrast, they noted that G. oregnonensis was active even at very low oxygen levels. In the present study, G. oregnonensis was positively correlated with algal weight despite the anoxic conditions.

Corophium spp.

Abundance of Corophium spp. ranged from 0 m^{-2} to 31,040 m^{-2} in June, and 0 m^{-2} to 14,848 m^{-2} in July. In July, Corophium spp. was more abundant at sites with fine sediments (i.e. silt or silt/sand mixtures) than at sites with coarser sediments. These data concur with the findings of Levings and Coustalin (1975) that small crustaceans such as Corophium spp. were most abundant in fine sediments on Sturgeon Banks. Abundance of this species in other estuaries (0 m^{-2} to 37,400 m^{-2} Sturgeon Banks; Levings

and Coustalin, 1975) (320 m^{-2} to 8,060 m^{-2} Maplewood mudflats in Burrard Inlet; Levings and McDaniel, 1974) and (x 396 m^{-2} mud/lower marsh microhabitats of the Squamish estuary; Levings, 1978) was in the same range as observed in the Campbell River estuary.

Polychaeta

In June abundance of polychaetes ranged from 0 m^{-2} to 10,272 m^{-2}, and in July from 0 m^{-2} to 79,104 m^{-2}. Polychaetes were more abundant in mud/sand substrates than in sand/gravel substrates.

Oligochaeta

Oligochaete numbers ranged from 0 m^{-2} to 31,872 m^{-2} in June and 48 m^{-2} to 50,304 m^{-2} in July. Distribution was similar to that of polychaetes, i.e. higher numbers in fine sediments.

FISH

Distribution and Abundance

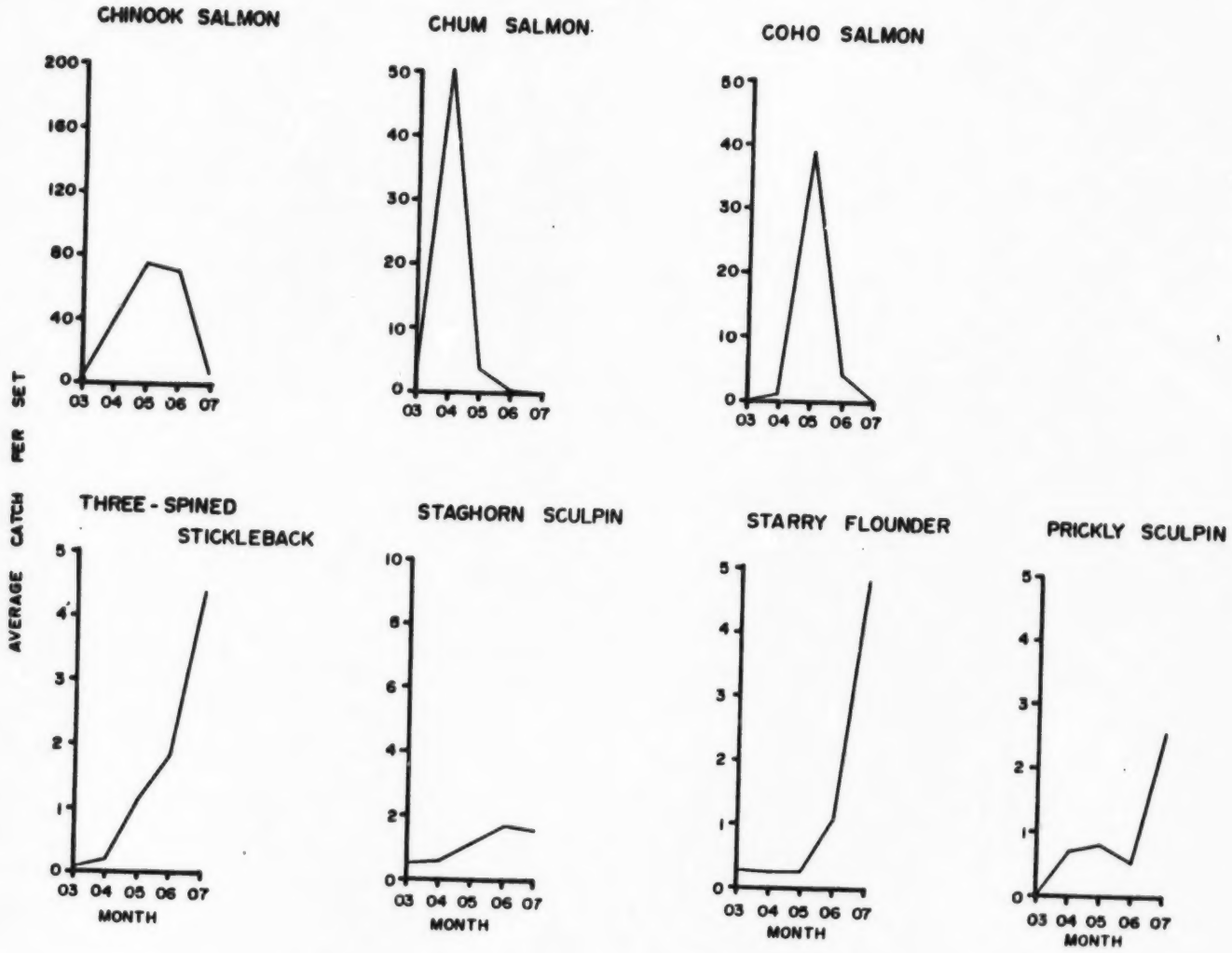
A total of 18 species of fish were captured in beach seine samples in the Campbell River estuary (Table 4).

Chinook Salmon: peak abundance in the estuary was observed during May and June (Figure 5). Approximately 512,000 hatchery chinook were released on each of two dates 29 May and 9 June 1980 (Van Tyne, 1980, pers. comm.). Catches of chinook in May would have been wild fish whereas in June both hatchery and wild

Table 4 Relative abundance of fish in the Campbell River Estuary (31 March - 31 July 1980).

Common Name	Species	Average Catch Per Set
Chinook salmon	*Oncorhynchus tshawytscha*	44.44
Chum salmon	*O. keta*	13.23
Coho salmon	*O. kisutch*	10.38
Pink salmon	*O. gorbuscha*	3.54
Three-spined stickleback	*Gasterosteus aculeatus*	1.25
Staghorn sculpin	*Leptocottus armatus*	1.06
Starry flounder	*Platichthys stellatus*	0.95
Prickly sculpin	*Cottus asper*	0.78
Crescent gunnel	*Pholis laeta*	0.22
Cutthroat trout	*Salmo clarki clarki*	0.07
Steelhead trout	*Salmo gairdneri*	0.07
Buffalo sculpin	*Enophrys bison*	0.05
Shiner perch	*Cymatogaster aggregata*	0.03
Pacific sandlance	*Ammodytes hexapterus*	0.02
Snake prickleback	*Lumpenus sagitta*	0.01
Bay pipefish	*Sygnathus griseolineatus*	0.01
Penpoint gunnel	*Apodichthys flavidus*	0.01
Tidepool snailfish	*Liparus florae*	0.01

FIGURE 5. TIMING OF ABUNDANCE OF COMMON FISH SPECIES AT CAMPBELL RIVER ESTUARY.



fish were caught. This is substantiated by the recovery of coded-wire tags in June and July, but not in May. That more fish were caught in the current of the main river channel than in any other habitat type suggests most hatchery chinook are move straight out to the estuary.

Chum salmon: were most abundant at the end of April (50.1 set^{-1}) and few were caught by June (0.36 set^{-1}) (Figure 5). Largest catches were taken in the main river channel at high tide and behind the bar at low tide. Chum were found throughout the estuary with noticeably higher catches in marsh habitats of all areas.

Coho salmon: were abundant in the estuary only in May (Figure 5) presumably resulting from hatchery releases on 20 April (83,000) and 5-30 May 1980 (1,226,000). Marked coho salmon from Quinsam Hatchery were recovered in the catch from the end of April to the end of June. Coho were most abundant off the gravel bar at the mouth of the main river channel at low tide. In areas other than the main river channel, coho salmon were common at low tide in the log sort and inside Baikie's Slough. Timing of coho salmon presence was similar at all habitats, that is, peak occurrence in May, except in the vicinity of Nunns Creek (including log sort marsh habitat) where coho salmon were most abundant in June.

Pink Salmon: compared to the other species of salmon, pinks were rarely found the estuary. After the hatchery release at the end of March, the average catch per set was only 1.3 fish. Hatchery fish reared in pens in the estuary were released the first week of May; however, no pink salmon were caught during this month. In June, average catch per set was 143 due to a large catch of pink salmon in the main river channel. These fish may have been from another river system.

Three-spined Stickleback: abundance increased during the study period (Figure 5). Sticklebacks were found throughout the estuary with the greatest abundance in marshes of Nunns Creek, in gravel areas of the log sort, on mud and debris in Baikie's Slough and in the main river channel at low tide.

Staghorn Sculpin: abundance peaked in June with the largest catches at high tide behind the bar at the mouth of the main channel (Figure 5). Catches were generally greater in low tide sets than in high tide sets.

Starry flounders: increased in abundance over the study period from an average 0.3 set^{-1} at the end of March to a peak of 4.8 set^{-1} at the end of July (Figure 5). Flounders were distributed throughout the estuary with highest catches taken from sand and sand/gravel substrates at the mouth of Nunns Creek, the mouth of Baikie's Slough, and the main channel. Timing of peak abundance varied between the above habitats from April (main channel) to July (mouth of Nunns Creek).

Prickly Sculpin: abundance increased from 0.02 set^{-1} at the end of March to 2.5 set^{-1} at the end of July (Figure 5). Although prickly sculpins were found throughout the estuary, they most abundant in Baikie's Slough. No prickly sculpins were caught behind the sandbar where staghorn sculpins were most abundant.

Lengths, Weights, Condition Factors and Age of Juvenile Salmon

Chinook salmon: juvenile wild stock increased in mean length from 41 mm (March) to 47 mm (May), and mean weight increased from 0.65 gm to 1.24 gm (Table 5). With the release of the hatchery stock in June, data on wild stock could not be separated. In

Table 5 Length, weight and condition factor of juvenile chinook salmon in the Campbell River Estuary (March-July 1980).

Month	Sample Size (n)	Small Juveniles n	Small Juveniles Length (mm)*	Small Juveniles Weight (g)*	Large Juveniles n	Large Juveniles Length (mm)*	Large Juveniles Weight (g)*	Condition* Factor
March	49	43	41 (37-45)	0.65 (0.60-0.74)	6	168 (149-185)	57.6 (42.2-77.6)	0.99 (0.73-1.4)
April	521	520	42 (36-56)	0.63 (0.41-2.57)	1	150	44.5	1.07 (0.75-1.5)
May	736	735	47 (36-65)	1.24 (0.47-3.73)	1	126	21.6	1.16 (0.64-1.81)
June**	572		(35-134)	(0.54-29.4)				1.23 (0.87-1.67)
July**	142		(52-139)	(1.85-40.3)				1.33

*mean (range)
**Samples were not separated into large and small groups and means were not calculated as several size classes were present

June, analysis of length data suggests that up to 3 stocks (wild, hatchery, second year class) of juvenile cinook may be present in the estuary.

The mean value of the condition factor, for all fish sampled showed a steady increase throughout the period from 0.99 in March to 1.33 in July. Mean condition factors for fish sampled from the Nunns Creek marsh sites and the main river channel at high tide, always exceeded the overall mean condition factor for each month. The mean condition factors for fish sampled in the north arm of Baikie's Slough were always lower than the overall mean condition factor for each month.

Chinook salmon aged 0+ (fry of the year) and 2_1 (two year olds with a winter spent in ocean or estuary) were present in the estuary from the end of April to the end of June.

Chum Salmon: juveniles increased in mean length from 34 mm in March to 65 mm in June (Table 6). The mean weight for this same period increased from 0.32 g to 3.01 g. Increases in length and weight were reasonably linear in March through May. The mean value of the condition factor also increased in a linear manner from March (0.80) through May, (0.89) then increased substantially to 0.98 in June.

The mean value of the condition factor for juvenile chum sampled in the log sort marsh (habitat type 43) and north arm of Baikie's Slough (habitat type 48) was always less than the overall monthly mean value. The mean value of the condition factor for juvenile chum sampled in the south arm of Baikie's Slough (habitat type 49) was always higher than the overall mean monthly condition factor value.

Table 6 Length, weight and condition factor of juvenile chum salmon in the Campbell River Estuary (March-June 1980).

Month	Sample Size (n)	Length*(mm)	Weight*(g)	Condition Factor*
March	73	34 (28-38)	0.32 (0.13-0.48)	0.80 (0.60-1.07)
April	503	37 (32-59)	0.42 (0.27-1.89)	0.85 (0.50-1.16)
May	161	40 (36-45)	0.53 (0.37-0.96)	0.89 (0.74-0.97)
June	24	65 (41-93)	3.01 (0.70-8.50)	0.98 (0.87-1.10)

* Mean (range)

Coho Salmon: length and weight data are generally representative of first year wild and hatchery stocks but may also include some second year wild or hatchery stock fish (Table 7). The majority of the hatchery stock was released in May. Due to the mixing of stocks monthly increases in length and weight may not necessarily represent growth. Mean monthly condition factor values varied irregularly, during the sampling period. A low value in May might be attributed to the release of hatchery coho. The mean condition factors for juvenile coho sampled in the log sort-marsh (habitat type 43) and main channel (habitat type 56) were below the overall mean monthly value.

Most coho salmon caught in the estuary including hatchery fish were aged 1+ (overwintered in fresh water). Some coho aged 0+ (fry of the year), 2_2 (just out of fresh water but with some ocean growth) and 3_2 (adult, should spawn in 1980) were caught in the estuary at the end of June.

Pink Salmon: fry were released from the hatchery in March. The mean monthly length of the juvenile pink increased from 31 mm in March to 34 mm in April, with corresponding increases in weight and condition factor (Table 8). The absence of juvenile pinks in the estuary in May, and the large length, weight and condition factors in June suggest that a different stock may have entered the estuary. The condition factor of pinks in the main river channel (habitat type 42) was always lower than the mean monthly value, whereas, at log sort (habitat type 44), condition factor was always higher than the mean.

Mark/Recapture Experiments

Results of the mark/recapture experiments are shown in Table 9.

Table 7 Length, weight and condition factor of juvenile coho salmon in the Campbell River Estuary (March-July 1980).

Month	Sample Size (n)	Length*(mm)	Weight*(g)	Condition Factor*
March	1	34	0.37	0.95
April	41	110 (82-134)	16.2 (6.9-25.9)	1.19 (0.83-1.41)
May	208	118 (53-175)	19.3 (1.9-68.1)	1.14 (0.81-1.80)
June	131	119 (50-185)	23.1 (1.6-67.3)	1.20 (0.93-1.50)
July	2	135 (108-162)	35.3 (16.3-54.3)	1.29 (1.28-1.30)

* Mean (range)

Table 8 Length, weight and condition factor of juvenile pink salmon in the Campbell River Estuary (March-June 1980).

Month	Sample Size (n)	Length*(mm)	Weight*(g)	Condition Factor*
March	54	31 (28-36)	0.23 (0.15-0.29)	0.75 (0.49-1.03)
April	20	34 (29-44)	0.34 (0.23-0.75)	0.81 (0.61-1.13)
June	46	79 (60-105)	5.3 (2.1-13.0)	1.01 (0.89-1.20)

* Mean (range

Table 9 Mark/Recapture Experiment Results

Test 1 (May 12-15)	Nunns Creek:	Marks released	1,595 RED
		Total captures	1,150
		Recaptured marks	8 RED
	Baikie's Slough:	Marks released	1,467 YELLOW
		Total captures	2,714
		Recaptured marks	3 YELLOW
	Site #6:	Marks released	0
		Total captures	154
		Recaptured marks	1 RED
Test 2 (Jun 9-12)	Nunns Creek:	Marks released	2,410 GREEN
		Total captures	3,110
		Recaptured marks	10 GREEN
			& 1 RED
	Baikie's Slough:	Marks released	2,706 RED
		Total captures	4,256
		Recaptured marks	14 RED
			& 2 GREEN
Site #15		Marks released	0
		Total captures	1,169
		Recaptured marks	1 GREEN
			& 7 RED
Site #6:		Marks released	0
		Total captures	1,249
		Recaptured marks	1 GREEN

Population estimates calculated using mark/recapture techniques were:

12-15 May 1980	Nunns Creek	229,281
	Baikie's Slough	1,327,146
9-12 June 1980	Nunns Creek	749,510
	Baikie's Slough	822,624

Since there was outmigration from the estuary, the population estimates can only be considered as instantaneous. However, since two marked chinook salmon juveniles were recaptured on 26 May 1980, and one marked chinook was recaptured on 24 June 1980, residence in the estuary for some fish was at least 2 weeks. Further, since several coded wire tagged chinook released from the hatchery in May 1980 were captured at the end of June 1980; chinook residency can at least one month. Recapture of marked fish at sites #6 and #15 indicate that juvenile salmon ranged widely throughout the estuary.

Juvenile Salmon Stomach Contents

The most common prey items in the juvenile salmon stomachs were estuarine benthic invertebrates (cyclopoid copepods, harpacticoid copepods, Eogammarus spp., Corophium spp., G. oregonensis, and mysids), immature (aquatic origin) and adult insects (aquatic and terrestrial origins) and planktonic crustaceans, especially marine and freshwater calanoid copepods and freshwater cladocerans. All species of juvenile salmonids fed on all of these prey items to some degree which suggests that they are opportunistic feeders.

The juvenile chinook salmon diet was particularly diverse compared to other species. Immature dipterans were the most

areas. The source of these insects was probably drift from upstream habitats.

REFERENCES CITED

American Public Health Association. 1975. Standard methods for the examination of water and wastewater. 14th Edition. American Public Health Association, Washigton, D.C.

Barko, J.W. and R.M. Smart. 1977. The growth and biomass distribution of two emergent freshwater plants, Cyperusesculentus and Scirpus validus, on different sediments. Aquatic Botany. 5: 109-117.

Beak Hinton Consultants Ltd. 1977. Environmental impact assessment of Roberts Bank port expansion. In: The existing biological environment. A report prepared for the National Harbours Board, Port of Vancouver. Vol. 4, Appendix B.

Brownlee, M.J., E.R. Mattice and C.D. Levings. 1984. The Campbell River Estuary: a report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for the purpose of estuarine rehabilitation. Can MS Rep. Fish. Aquat. Sci. 1798: 54 p.

Chapman, V.J. and D.J. Chapman. 1973. The algae. 2nd Edition. MacMillan and Company Publishers. London, England. 497 pp.

Department of the Environment. 1976. Surface water data, British Columbia to 1975. Water Survey of Canada, InlandWaters Directorate, Ottawa, Ont. 308 pp. Cited in: Bell, L.M. and J.M. Thompson.

Envirocon. 1980. Fraser River habitat development program criteria summary report. Prepared for Fisheries and Oceans, Canadian Wildlife Service, Public Works Canada. Vancouver, B.C. Project #EA1830.

EVS Consultants Ltd. 1978. A study of the biological impacts and economics of primary forest industries in the Campbell River estuary. Volume II. Biological Report. Prepared for Elk River Timber Company and Raven Lumber Limited, Campbell River, B.C. 62 pp. plus tables and figures.

Healey, M.C. 1979. Detritus and juvenile salmon production in the Nanaimo estuary. I. Production and feeding rates of juvenile chum salmon (Oncorhynchus keta). J. Fish. Res. Board Can. 36: 488-496.

Healey, M.C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, Oncorhynchus tshawytscha. Fish. Bull. 77: 653-668.

Healey, M.C., F.P. Jordan, and R.M. Hungar. 1976. Laboratory and field evaluation of fluorescent grit as a marking material for juvenile salmonids. Fish. Res. Bd. Canada, MS Rep. 1392. 17 pp.

Hitchcock, C.L. and A. Cronquist. 1976. Flora of the Pacific Northwest. Univ. of Washington Press. 730 pp.

Kistritz, R.V. and I. Yesaki. 1979. Primary production, detritus flux and nutrient cycling in a sedge marsh, Fraser River estuary. Westwater Research Centre, U.B.C. Tech. Rept. No. 17. 53 pp.

Levings, C.D. 1974. River diversion and intertidal benthos at the Squamish River delta, British Columbia. p 193-202. In: Fresh water on the sea. Proceedings from a symposium on the influence of freshwater outflow on biological processes in fjords and coastal waters, 22-25 April 1974, Geilo, Norway. Stig Skreslet, Reidar Leinbo, John B.L. Matthews, and Egil Sakshaug (Editors).

Levings, C.D. . 1976. Industrial disruption of invertebrate communities on beaches in Howe Sound, B.C. Environment Canada. Fish. Mar. Serv. Tech. Rep. No. 663. 92 pp.

Levings, C.D. 1978 M.S. Consequences of port construction for benthic communities and habitats at the Squamish River estuary. B.C. Department of Fisheries and Oceans, West Vancouver, B.C. 23 pp.

Levings, C.D., and J.B. Coustalin. 1975. Benthic ecology studies on the tidal flats of Sturgeon and Roberts Bank in relation to present and projected industrial development. In: Department of Environment, Fisheries and Marine Service. Fisheries resources and food web components of the Fraser River estuary and an assessment of the impacts of proposed expansion of the Vancouver International Airport and other developments on these resources.

Levings, C.D., and N.G. McDaniel. 1974. Invertebrates at the Maplewood mudflats, a rare habitat in Vancouver Harbour, B.C. Fish. Mar. Serv. MS 1314. 22 pp.

Levings, C.D., and A.I. Moody. 1976. Studies of intertidal vascular plants, especially sedge (Carex lyngbyei), on the

disrupted Squamish River delta, British Columbia. Fisheries and Marine Service Tech. Report 606. 56 pp.

Levy, D.A., T.G. Northcote, and G.J. Birch. 1979. Juvenile salmon utilization of tidal channels in the Fraser River estuary, British Columbia. Westwater Research Centre. Tech. Rep. No. 23. 70 pp.

Lim, P.G., and C.D. Levings. 1973. Distribution and biomass for intertidal vascular plants on the Squamish delta. Fisheries Research Board Canada. MS Rep. No. 1219. 26 pp.

Moody, R. 1978a. Habitat, population and morphological charac-teristics of Zostera marina on Roberts Bank, B.C. Dept. of Plant Science, U.B.C., Vancouver, B.C. Unpubl. thesis.

Moody, A.I. 1978b. Growth and distribution of marsh plants on the southern Fraser delta foreshore. Dept. of Plant Science, U.B.C., Vancouver, B.C. Unpubl. thesis.

Naiman, R.J., and J.R. Sibert. 1979. Detritus and juvenile salmon production in the Nanaimo Estuary. III. Importance of detrital carbon to the estuarine ecosystem. J. Fish. Res. Board. Can. 36: 504-520.

Northcote, T.G., N.T. Johnston, and K. Tsumura. 1976. Benthic, epibenthic, and drift fauna of the lower Fraser River. Westwater Research Centre. Tech. Rept. No. 11. 227 pp.

Odum, E.P. 1971. Estuarine ecology. In: Fundamentals of ecology. W.B. Saunders Company, Toronto, Ont. 574 pp.

Pinkas, L., M.S. Oliphant, and I.L.K. Iverson. 1971. Food habitats of albacore, bluefin tuna, and bonito in California water. Calif. Fish and Game, Fish, Bull. 152: 1-105. Cited in: Caillet, G.M. 1976. Several approaches to the feeding ecology of fishes. In: Fish food habits studies. 1st Pacfiic Northwest Technical Workshop. G.A. Simenstad and S.J. Lipovsky (eds.) University of Washington. pp 1-13.

Pomeroy, W.M. 1977. Benthic algal ecology and primary pathways of energy flow on the Squamish River delta, British Columbia. Dept. of Botany, U.B.C., Vancouver, B.C. Unpubl. thesis.

Pomeroy, W.M. (In Prep.) Primary pathways of energy flow at the Squamish River estuary, British Columbia, with emphasis on

the benthic algal community. Department of Fisheries and Oceans, West Vancouver, B.C.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Department of Environment, Fisheries and Marine Service, Bull. #191, 382 p.

Scagel, R.F. 1972. Guide to common seaweeds of British Columbia. British Columbia Provincial Museum Handbook, No. 27. 330 pp.

U.S. Army Engineers. 1978. Wetland and habitat development with dredged material: engineering and plant propagation. Synthesis of research results. Tech. Rept. D5-78-16.

Yamanaka, K. 1975. Primary productivity of the Fraser River delta foreshore: yield estimates of emergent vegetation. Dept. of Plant Science, U.B.C., Vancouver, B.C. Unpubl. thesis.

Yeomens, W.C. 1973. Campbell River outdoor recreation and environmental survey. Report for the Regional District of Comox-Strathcona. 55 pp plus appendices.

Personal Communications

Hutchinson, I. 1981. Personal communication. Simon Fraser University, Burnaby, B.C.

Munroe, K. 1980. Personal communication. Dept. of Fisheries and Oceans. West Vancouver, B.C.

Pomeroy, W.M. 1981. Personal communication. Environmental Protection Service, Vancouvr, B.C.

Van Tyne, J. 1980. Personal communication. Hatchery Manager, Quinsam Hatchery, Department of Fisheries and Oceans, Campbell River, B.C.

ANNEX 1

LOCATION OF SAMPLE SITES

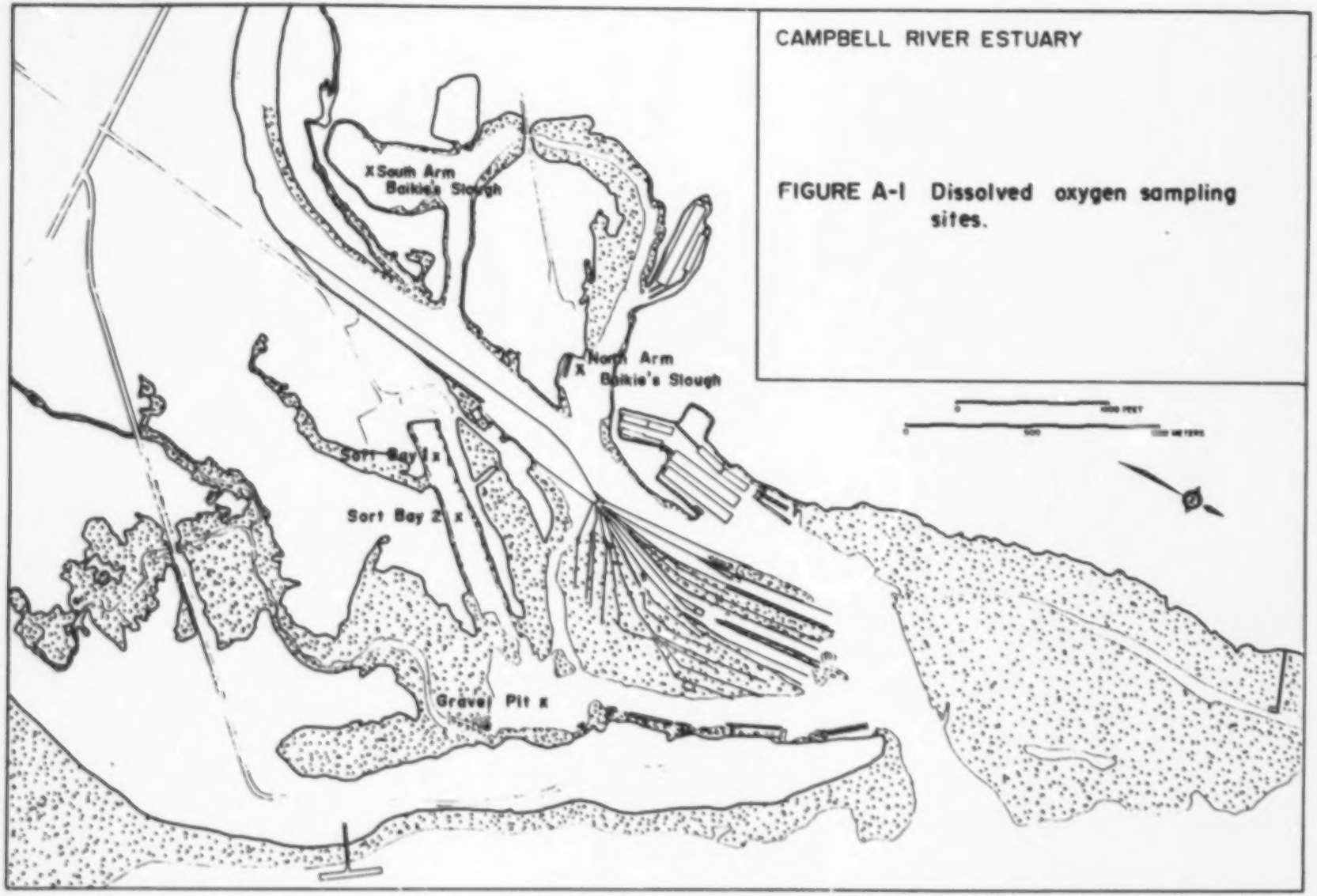
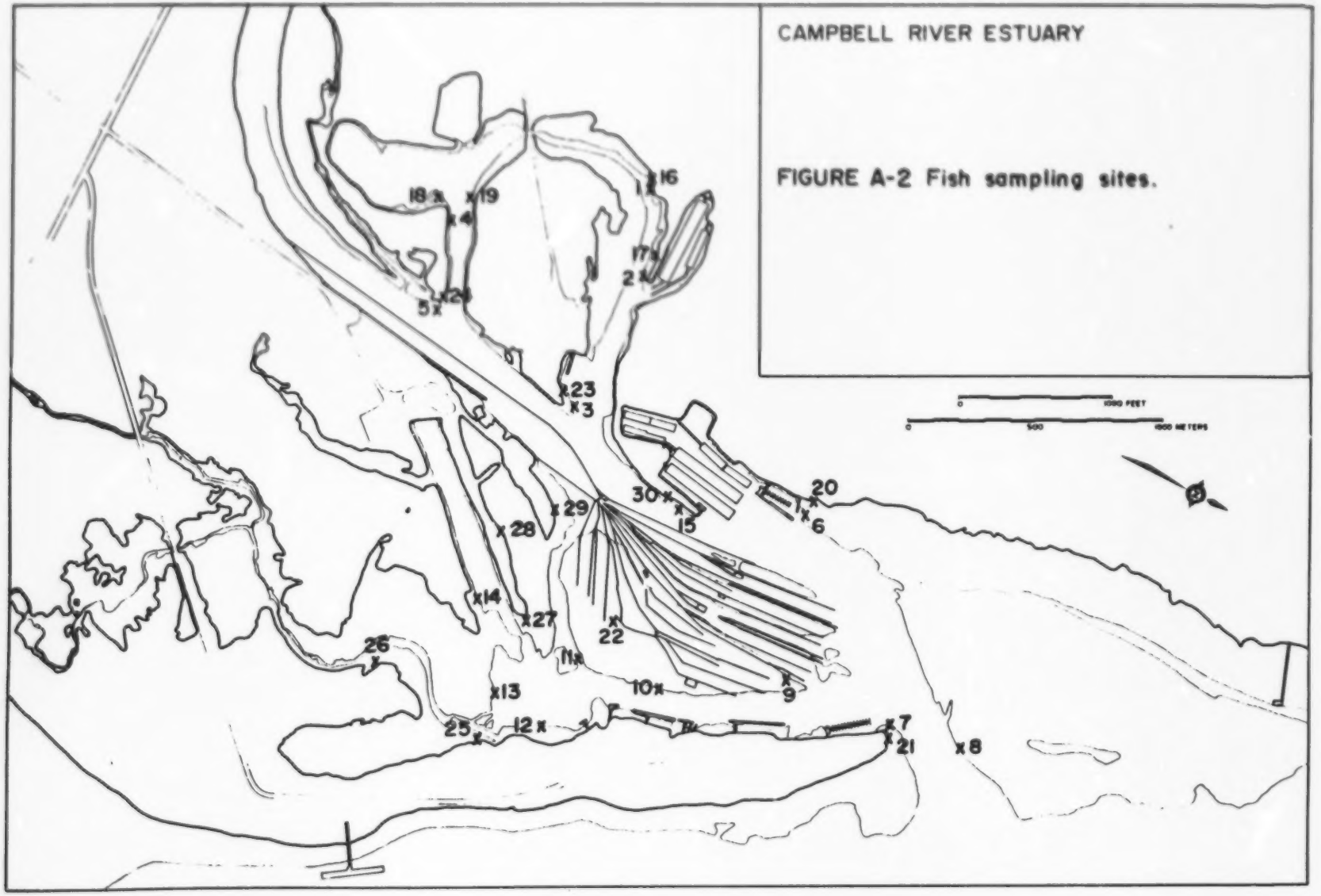
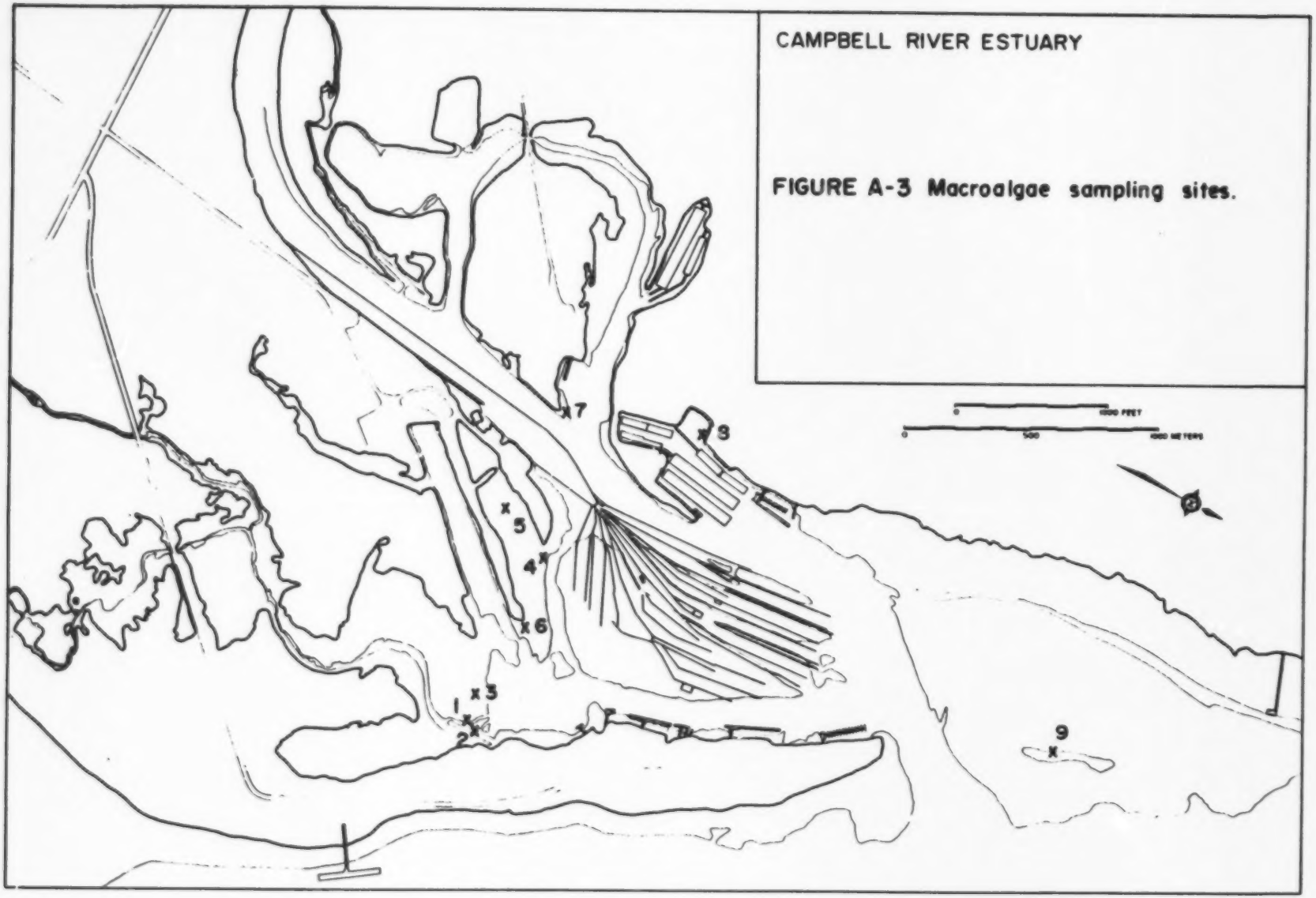
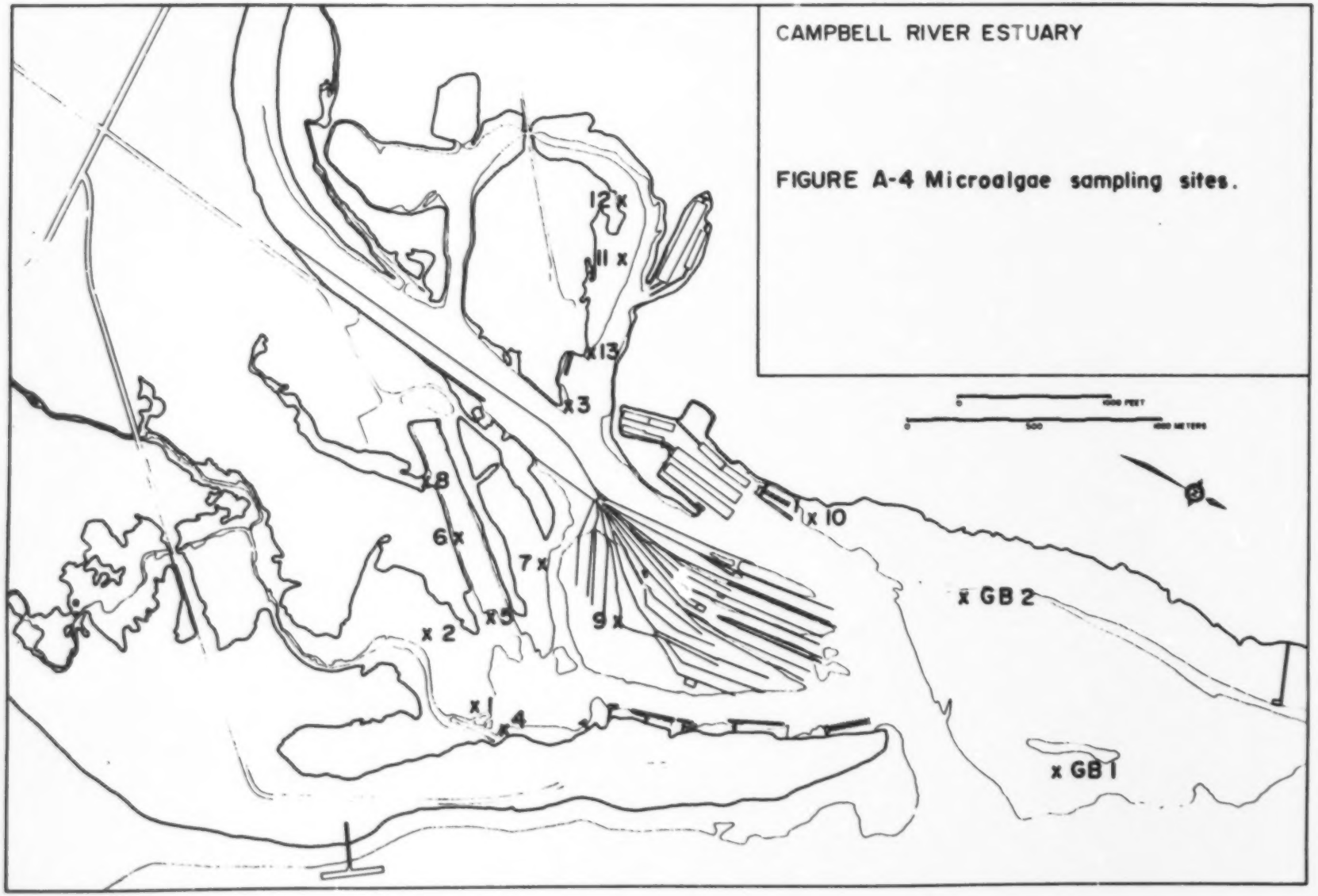
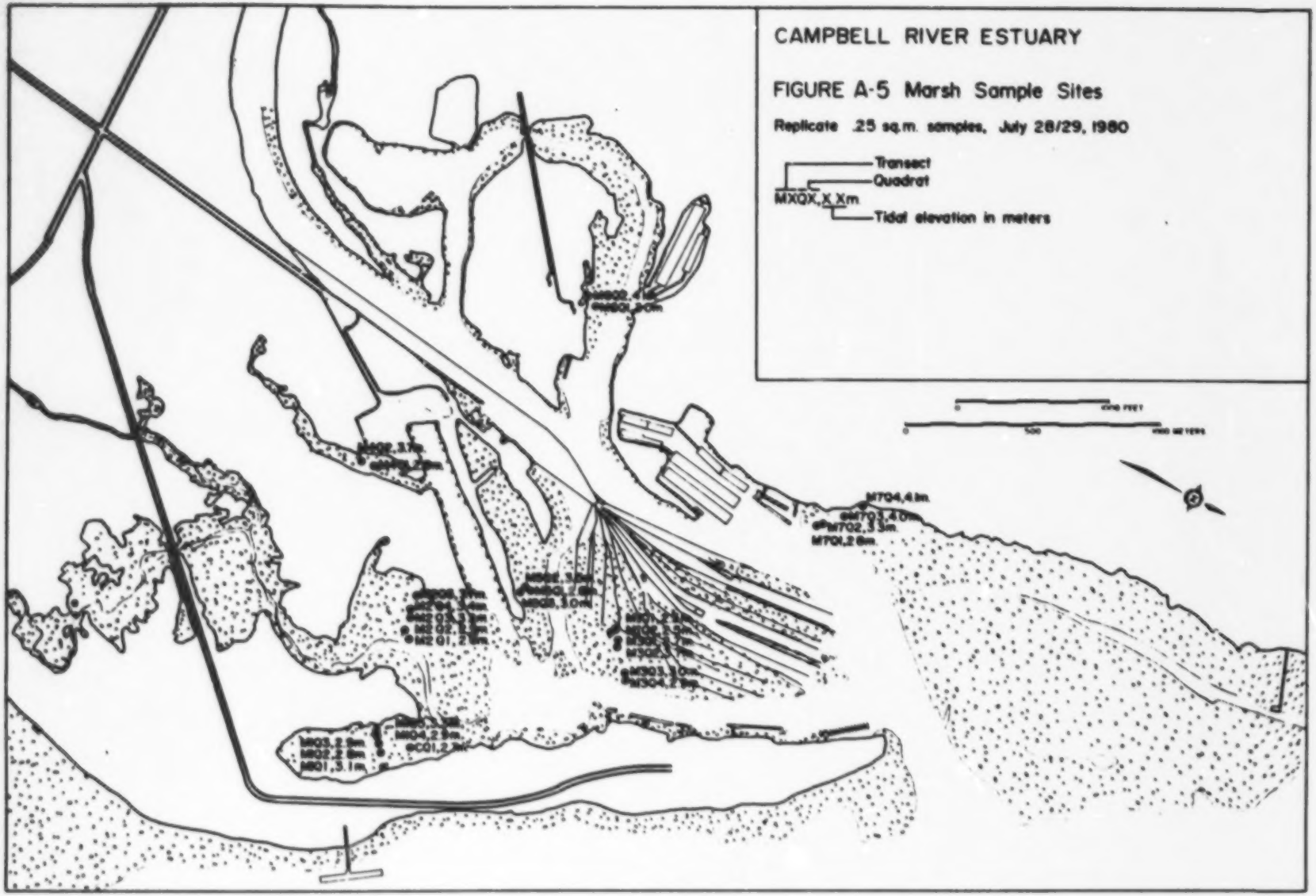


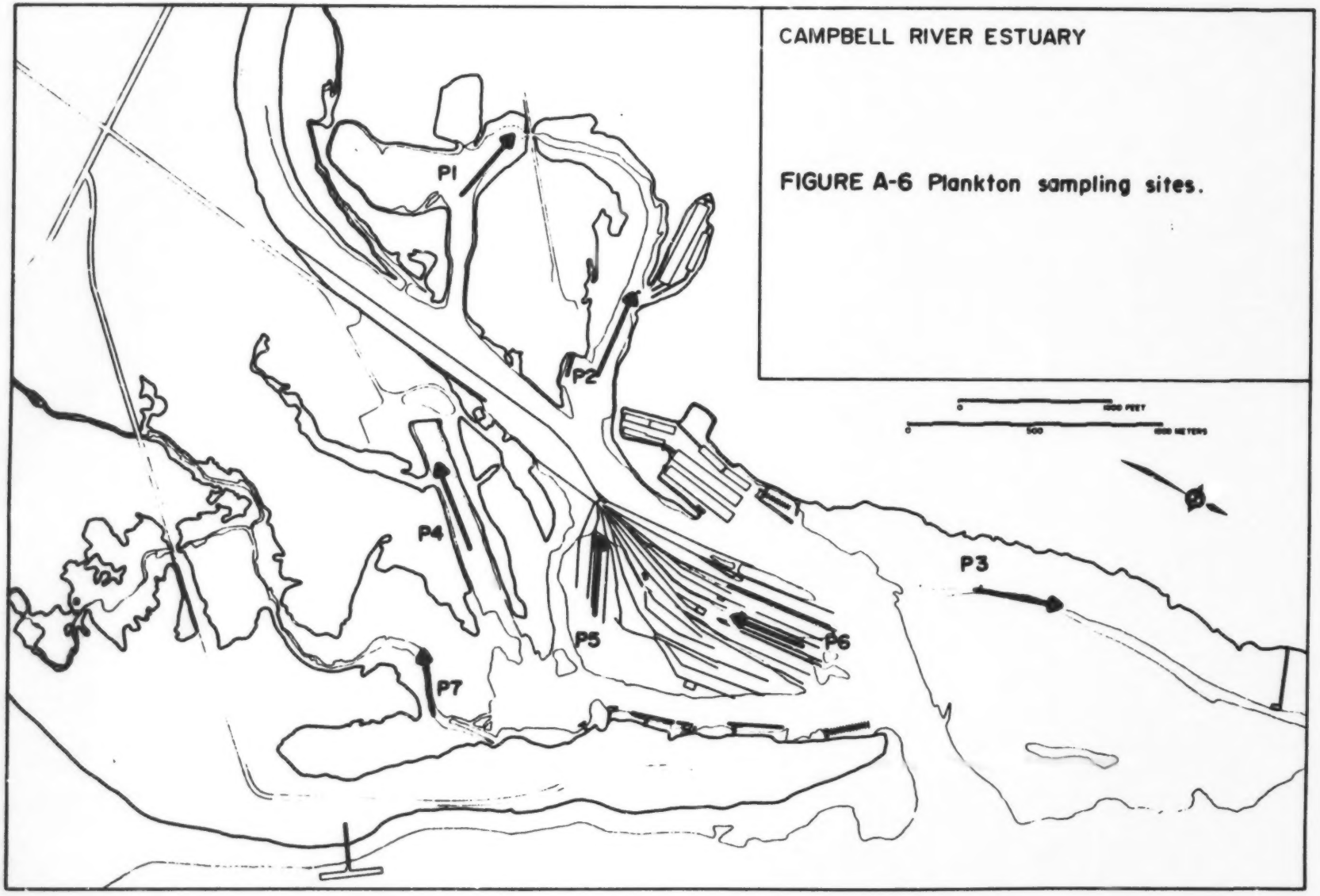
FIGURE A-1 Dissolved oxygen sampling sites.

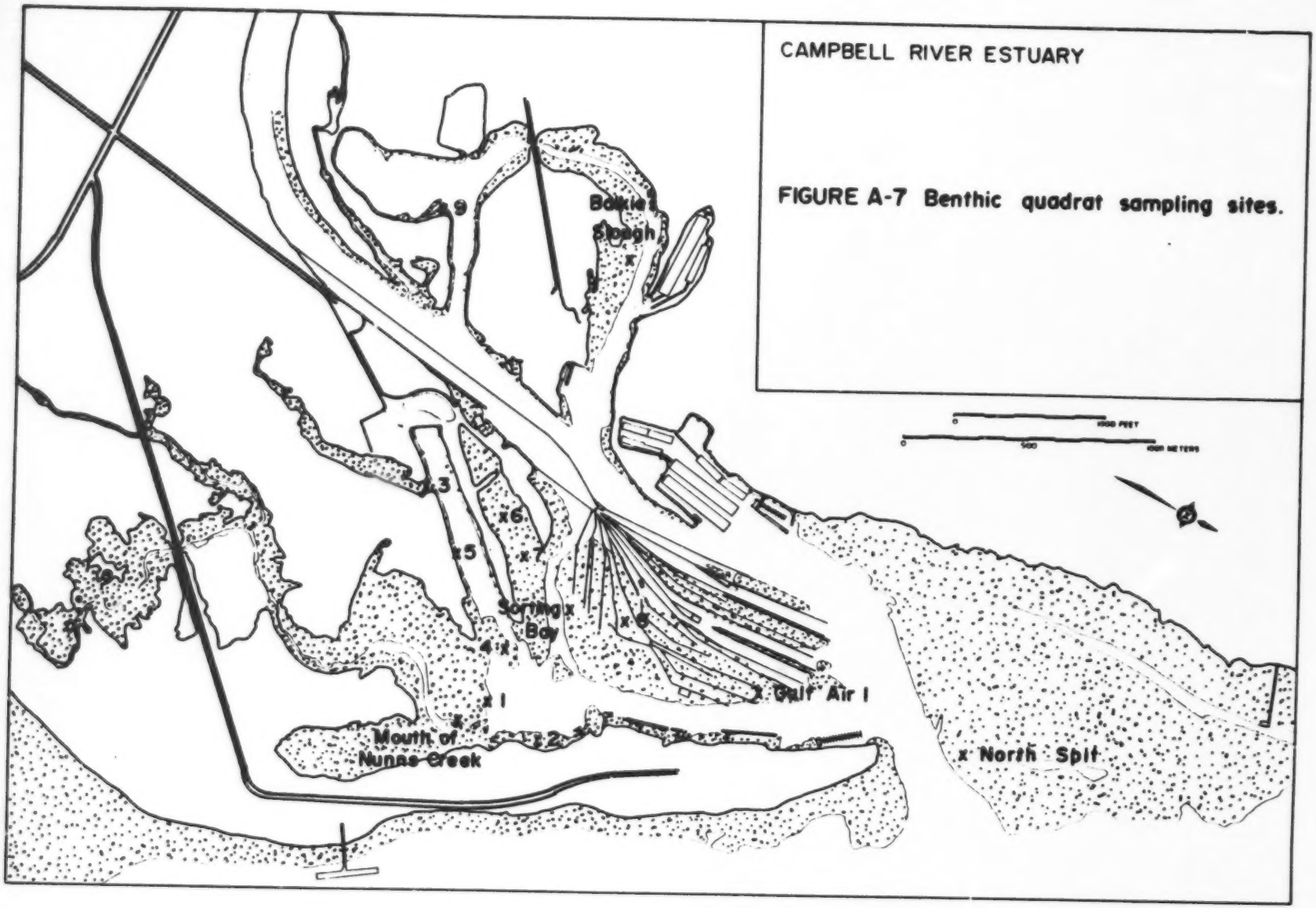

CAMPBELL RIVER ESTUARY
FIGURE A-2 Fish sampling sites.
1000 FEET
500
1000 METERS
16
18
19
4
17
2
5
24
23
3
30
15
20
1
6
29
28
14
27
22
26
11
10
9
13
25
12
7
21
8


CAMPBELL RIVER ESTUARY
FIGURE A-3 Macroalgae sampling sites.
1
2
3
4
5
6
7
8
9


CAMPBELL RIVER ESTUARY
FIGURE A-4 Microalgae sampling sites.
12 x
11 x
x13
x3
x8
6x
7x
x 10
x GB 2
x 2
x5
9x
x1
x4
x GB 1


CAMPBELL RIVER ESTUARY
FIGURE A-5 Marsh Sample Sites
Replicate .25 sq.m. samples, July 28/29, 1980
Transect
Quadrat
MXQX.X Xm
Tidal elevation in meters
M704,4.1m
M703,4.0m
M702,3.3m
M701,2.6m


CAMPBELL RIVER ESTUARY
FIGURE A-6 Plankton sampling sites.
P1
P2
P3
P4
P5
P6
P7


CAMPBELL RIVER ESTUARY
FIGURE A-7 Benthic quadrat sampling sites.
Bakkie's Slough
Sorting Bay
Gulf Air I
North Spit
Mouth of Nunns Creek
x1
x2
x3
x4
x5
x6
x7
x8
x9